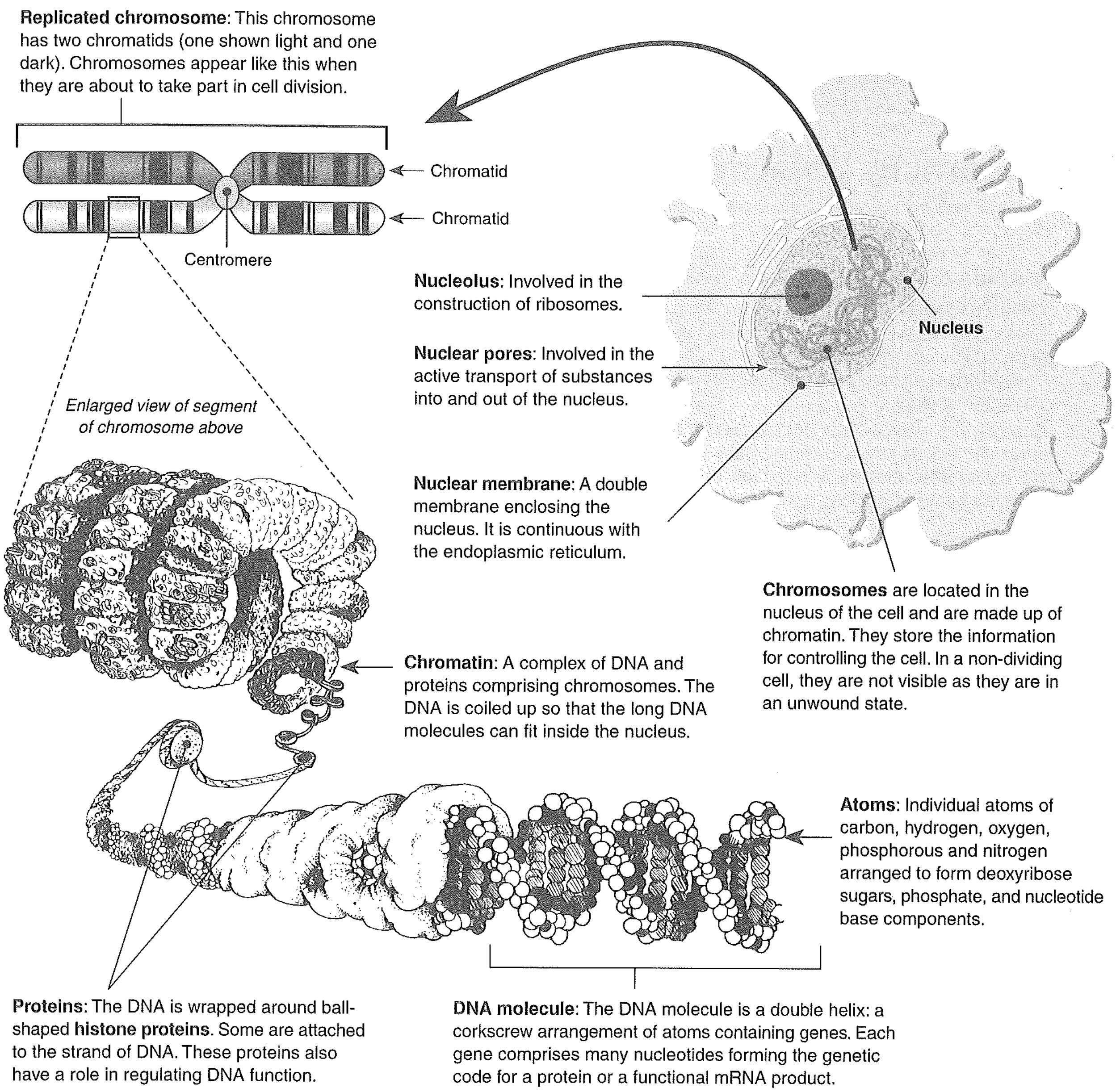
# The Role of DNA in Cells

A cell's total genetic endowment of DNA is called its **genome**. Arranged along the length of each DNA molecule are hundreds of thousands of genes: the hereditary units that specify an organism's characteristics. Every cell in the body of an organism contains **all** the genes for **all** the body's metabolism. When cells take on a specific role, such as that of a skin cell, only the information required for that cell's function is carried out. Other genes are turned off. The genetic instructions from the nucleus are carried to the cytoplasm where they are used to create proteins by protein synthesis. In eukaryotes, the DNA is coiled and folded into **chromosomes**. Chromosomes are visible with a light microscope just before and during cell division. Every species has a characteristic number of chromosomes in each nucleus (e.g. humans have 46 chromosomes in somatic cells). Reproductive cells (gametes) have half as many chromosomes as somatic cells (23 in humans).

## The Structure and Role of the Nucleus




1. Describe the general role of the nucleus: ______________________________

______________________________

2. The DNA in chromosomes is extremely long. Describe how this DNA is packaged inside the nucleus:

______________________________

______________________________

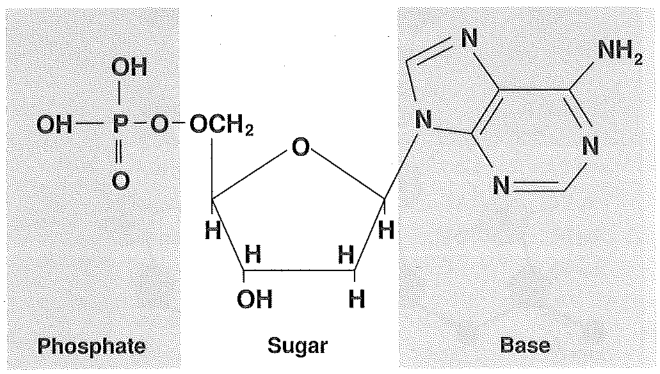
3. Explain when in the cell cycle a chromosome consists of a:

(a) Single chromatid: ______________________ (b) Two chromatids: ______________________

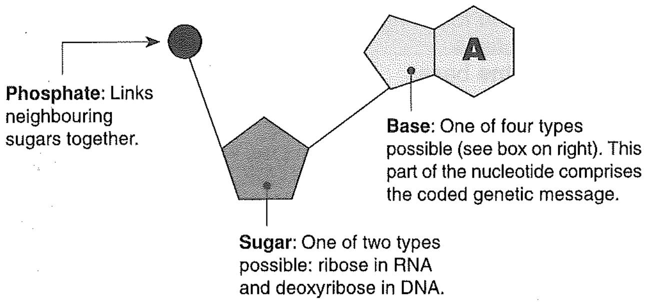
# Nucleic Acids

Nucleic acids are a special group of chemicals in cells concerned with the transmission of inherited information. They have the capacity to store the information that controls cellular activity. The central nucleic acid is called **deoxyribonucleic acid** (DNA). DNA is a major component of chromosomes and is found primarily in the nucleus, although a small amount is found in mitochondria and chloroplasts. Other **ribonucleic acids** (RNA) are involved in the 'reading' of the DNA information. All nucleic acids are made up of simple repeating units called **nucleotides**, linked together to form chains or strands, often of great length (see the activity *DNA Molecules*). The strands vary in the sequence of the bases found on each nucleotide. It is this sequence which provides the 'genetic code' for the cell. In addition to nucleic acids, certain nucleotides and their derivatives are also important as suppliers of energy (**ATP**) or as hydrogen ion and electron carriers in respiration and photosynthesis (NAD, NADP, and FAD).

### Chemical Structure of a Nucleotide

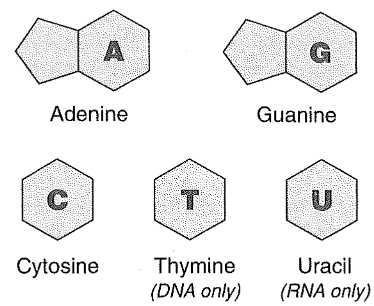



### Symbolic Form of a Nucleotide



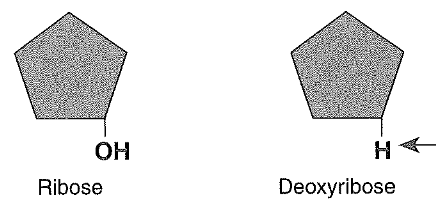

**Nucleotides** are the building blocks of DNA. Their precise sequence in a DNA molecule provides the genetic instructions for the organism to which it governs. Accidental changes in nucleotide sequences are a cause of mutations, usually harming the organism, but occasionally providing benefits.

### Bases



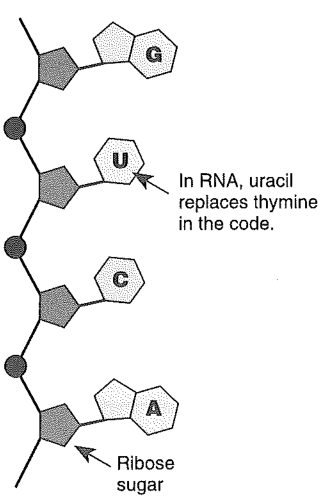

The two-ringed bases above are **purines** and make up the longer bases. The single-ringed bases are **pyrimidines.** Although only one of four kinds of base can be used in a nucleotide, **uracil** is found only in RNA, replacing **thymine.** DNA contains: A, T, G, and C, while RNA contains A, U, G, and C.

### Sugars



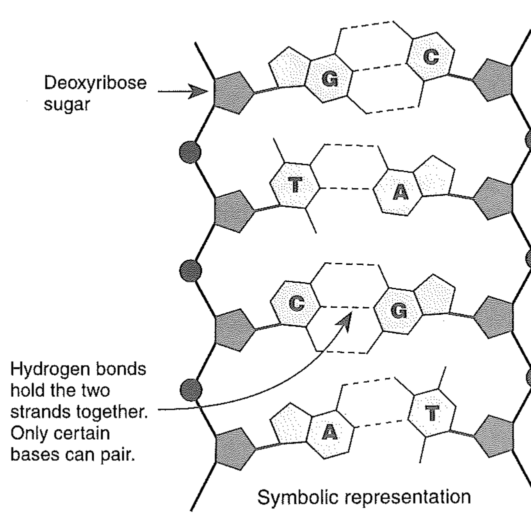

**Deoxyribose** sugar is found only in DNA. It differs from **ribose** sugar, found in RNA, by the lack of a single oxygen atom (arrowed).

### RNA Molecule



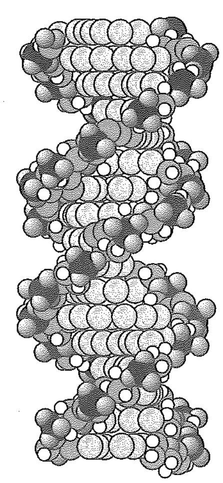

**Ribonucleic acid** (RNA) comprises a *single strand* of nucleotides linked together.

### DNA Molecule




Symbolic representation

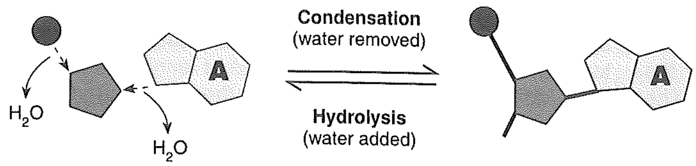
### DNA Molecule



Space filling model

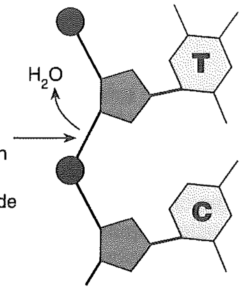
**Deoxyribonucleic acid** (DNA) comprises a *double strand* of nucleotides linked together. It is shown unwound in the symbolic representation (left). The DNA molecule takes on a twisted, double helix shape as shown in the space filling model on the right.

## Formation of a nucleotide




A nucleotide is formed when phosphoric acid and a base are chemically bonded to a sugar molecule. In both cases, water is given off, and they are therefore condensation reactions.

## Formation of a dinucleotide

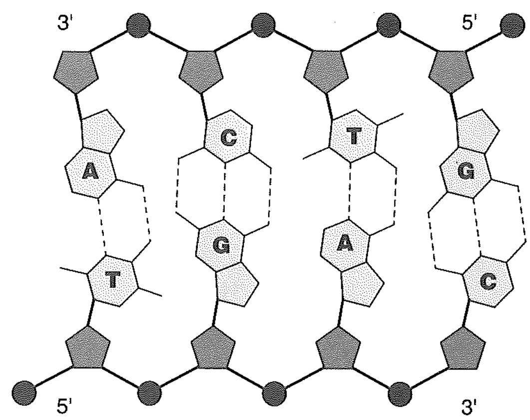



Two nucleotides are linked together by a condensation reaction between the phosphate of one nucleotide and the sugar of another.

### Double-Stranded DNA

The **double-helix** structure of DNA is like a ladder twisted into a corkscrew shape around its longitudinal axis. It is 'unwound' here to show the relationships between the bases.

- The way the correct pairs of bases are attracted to each other to form hydrogen bonds is determined by the number of bonds they can form and the shape (length) of the base.
- The **template strand** the side of the DNA molecule that stores the information that is transcribed into mRNA. The template strand is also called the **antisense strand**.
- The other side (often called the **coding strand**) has the same nucleotide sequence as the mRNA except that T in DNA substitutes for U in mRNA. The coding strand is also called the **sense strand**.




1. The diagram above depicts a double-stranded DNA molecule. Label the following parts on the diagram:
   (a) **Sugar** (deoxyribose)
   (b) **Phosphate**
   (c) **Hydrogen bonds** (between bases)
   (d) **Purine** bases
   (e) **Pyrimidine** bases

2. (a) Explain the **base-pairing rule** that applies in double-stranded DNA: ______________________

   ______________________________________________

   (b) Explain how this differs in mRNA: ______________________

   (c) Describe the purpose of the hydrogen bonds in double-stranded DNA: ______________________

   ______________________________________________

3. Describe the functional role of nucleotides: ______________________

   ______________________________________________

4. Distinguish between the **template strand** and **coding strand** of DNA, identifying the functional role of each:

   ______________________________________________

   ______________________________________________

   ______________________________________________

5. Complete the following table summarising the differences between DNA and RNA molecules:

| | DNA | RNA |
|---|---|---|
| Sugar present | | |
| Bases present | | |
| Number of strands | | |
| Relative length | | |

# DNA Molecules

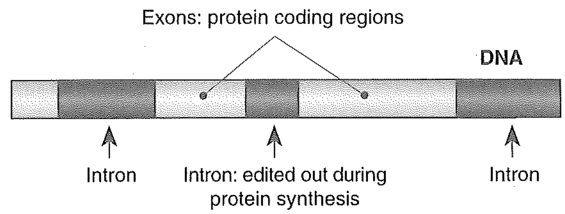
Even the smallest DNA molecules are extremely long. The DNA from the small *Polyoma* virus, for example, is 1.7 µm long; about three times longer than the longest proteins. The DNA comprising a bacterial chromosome is 1000 times longer than the cell into which it has to fit. The amount of DNA present in the nucleus of the cells of eukaryotic organisms varies widely from one species to another. In vertebrate sex cells, the quantity of DNA ranges from 40 000 **kb** to 80 000 000 **kb**, with humans about in the middle of the range. The traditional focus of DNA research has been on those DNA sequences that code for proteins, yet protein-coding DNA accounts for less than 2% of the DNA in human chromosomes. The rest of the DNA, once dismissed as non-coding 'evolutionary junk', is now recognised as giving rise to functional RNA molecules, many of which have already been identified as having important regulatory functions. While there is no clear correspondence between the complexity of an organism and the number of protein-coding genes in its genome, this is not the case for non-protein-coding DNA. The genomes of more complex organisms contain much more of this so-called "non-coding" DNA. These RNA-only 'hidden' genes tend to be short and difficult to identify, but the sequences are highly conserved and clearly have a role in inheritance, development, and health.

**Sizes of DNA Molecules**

| Group | Organism | Base pairs (in 1000s, or kb) | Length |
|---|---|---|---|
| Viruses | Polyoma or SV40 | 5.1 | 1.7 µm |
| | Lambda phage | 48.6 | 17 µm |
| | T2 phage | 166 | 56 µm |
| | *Vaccinia* | 190 | 65 µm |
| Bacteria | Mycoplasma | 760 | 260 µm |
| | *E. coli* (from human gut) | 4600 | 1.56 mm |
| Eukaryotes | Yeast | 13 500 | 4.6 mm |
| | *Drosophila* (fruit fly) | 165 000 | 5.6 cm |
| | Human | 2 900 000 | 99 cm |

### Kilobase (kb)

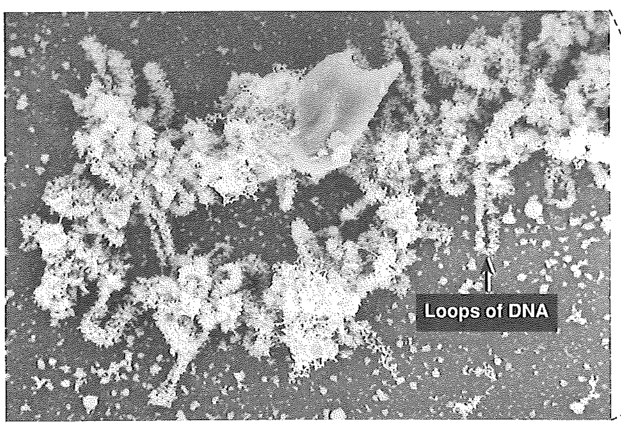
A kilobase is unit of length equal to 1000 base pairs of a double-stranded nucleic acid molecule (or 1000 bases of a single-stranded molecule). One kb of double stranded DNA has a length of 0.34 µm. (1 µm = 1/1000 mm)

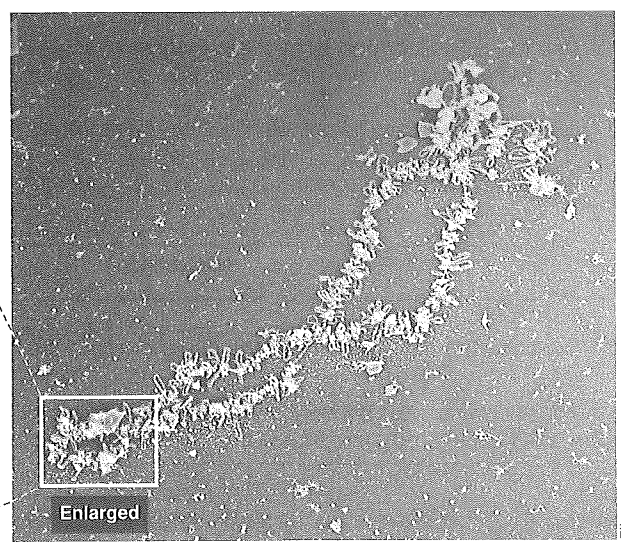



Most protein-coding genes in eukaryotic DNA are not continuous and may be interrupted by 'intrusions' of other pieces of DNA. Protein-coding regions (**exons**) are interrupted by non-protein-coding regions called **introns**. Introns range in frequency from 1 to over 30 in a single 'gene' and also in size (100 to more than 10 000 bases). Introns are edited out of the protein-coding sequence during protein synthesis, but probably, after processing, go on to serve a regulatory function.

### Giant lampbrush chromosomes

Lampbrush chromosomes are large chromosomes found in amphibian eggs, with lateral loops of DNA that produce a brushlike appearance under the microscope. The two scanning electron micrographs (below and right) show minute strands of DNA giving a fuzzy appearance in the high power view.




EII

1. Consult the table above and make the following comparisons. Determine how much more DNA is present in:

   (a) The bacterium *E. coli* compared to the Lambda Phage virus: ______________________

   (b) Human cells compared to the bacteria *E. coli:* ______________________

2. State what proportion of DNA in a eukaryotic cell is used to code for proteins or structural RNA: ______________

3. Describe two reasons why geneticists have reevaluated their traditional view that one gene codes for one polypeptide:

   (a) ______________________________________________

   ______________________________________________

   (b) ______________________________________________

   ______________________________________________